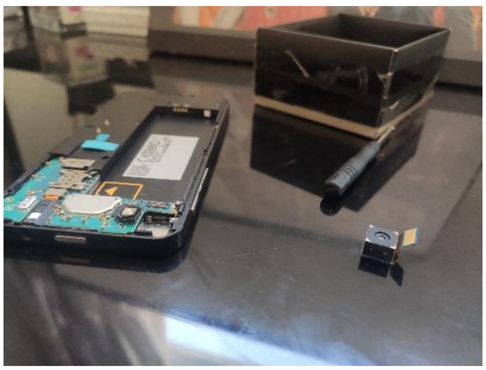
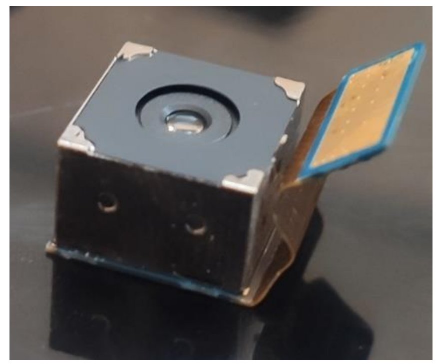
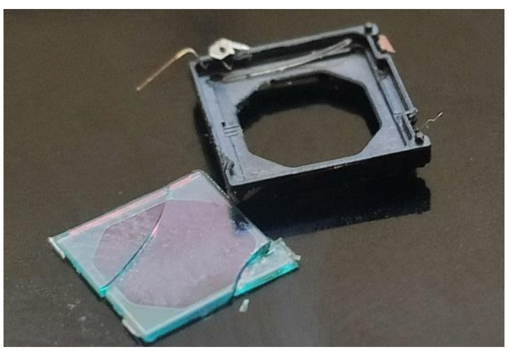
3.2.1 CONSTRUCTING THE CAMERA SYSTEM

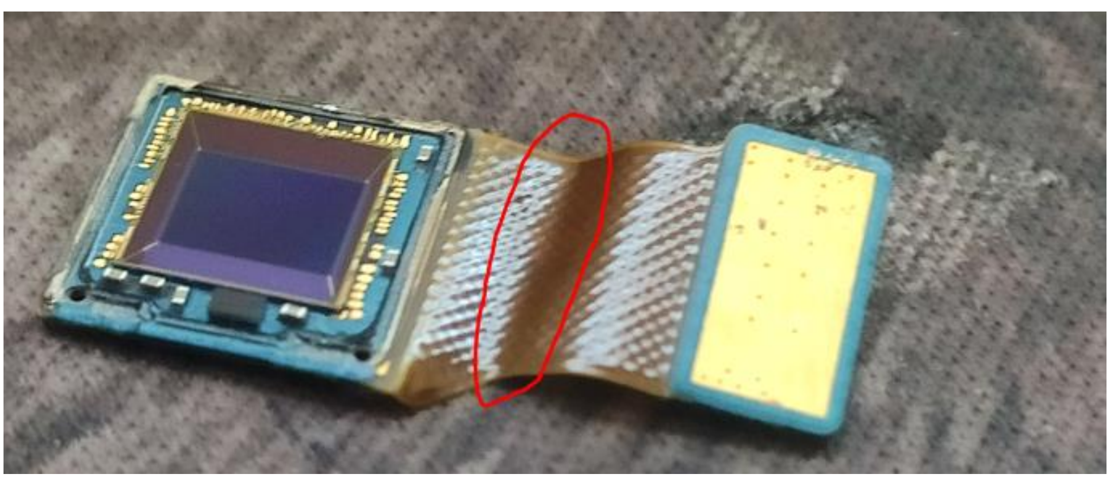
DIY (DO it yourself) concept was used to build the camera system at home. Old smartphone and tablets are used in the experiment to modify the camera system. First attempt was applied on the rear camera of BlackBerry RFG81UW mobile phone. The extraction process of the camera was successful, but the filter removal process got wrong due to damage in the wires that connects to the smartphone.







Filter is removed from the camera as shown in the figure. This is the filter which blocked the near infrared rays going into the sensor of the camera.



While we remove the filter the lens, sensor and the cover remain apart. Unfortunately, while recombining them the wire of the sensor got damaged. The figure above marks the damage area in the red circle where wire was torn accidently in the reassembly process. However, this experiment

3.2 CAMERA SYSTEM FOR NDVI

In [75] and [76] we have noticed that digital camera and the proper combination of digital cameras can be utilized to make a multispectral camera system. Our methodology is also dependent upon such concept. We will be using the camera of a digital camera to get our multispectral range. The wavelength of the visible spectral band approximately ranges from 400nm to 670 nm and that of Near-Infrared approximately ranges from 700nm to 1100nm. The camera present on normal smartphones captures the visible rays along with some minor near-infrared rays [76]. The camera system contains a filter that removes any further near infrared rays. However, some near-infrared passes with low intensity.

The following demonstration shows the near-infrared light emitted by any remote control of modern-day electronic device with the smartphone camera with and without near infrared filter:

Figure 3.2.1

Figure 3.2.2

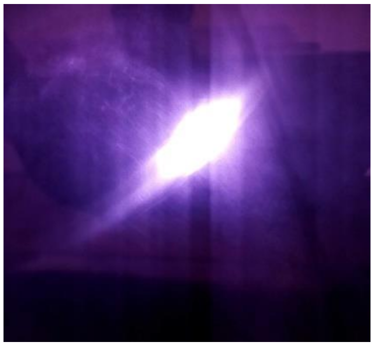


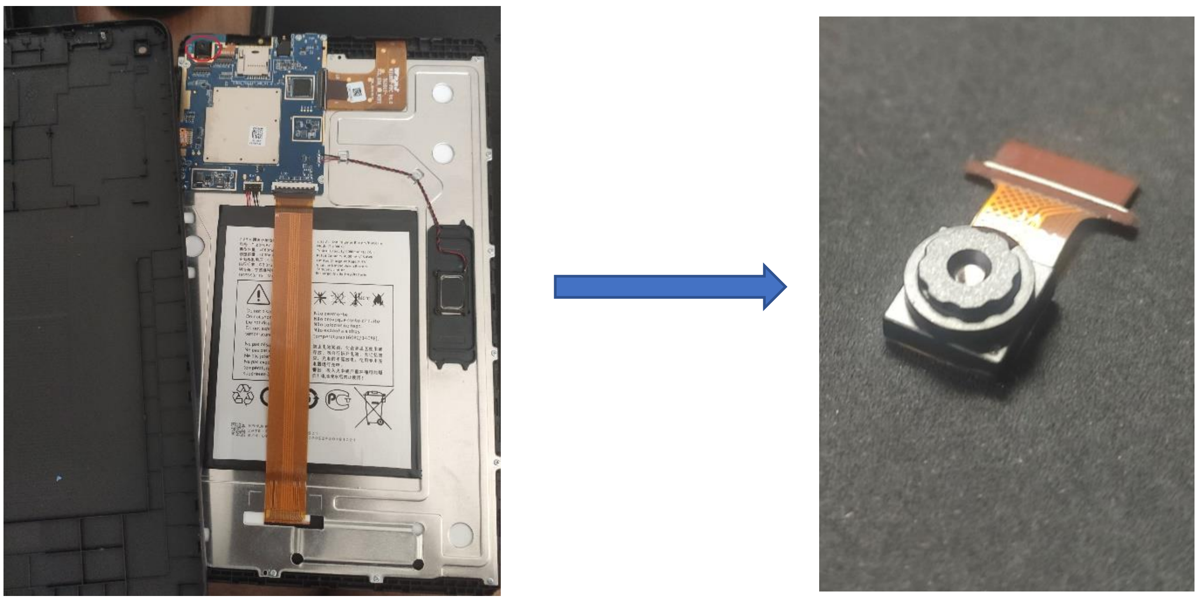
Figure 3.2.2

First figure represents the photograph of the remote controller of the TV without any button pressed. Figure 3.2.2 represents the photo when one of the buttons is pressed and a low intensity of a non-modified smartphone digital camera senses it. The third photograph is of the same remote controller taken by the camera of a smartphone whose filter is removed. The photograph below shows how high the intensity of near infrared light is emitted by the remote controller.

proved to be practice for extracting filters from the digital cameras from smartphones or tablet phones.

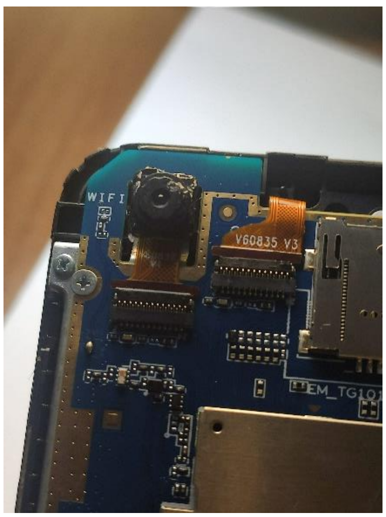
RETRY

After the unsuccessful first attempt the same method was applied on the ALCATEL 10-inch tablet. This time more focus was given for the operation. All parts were handled very carefully with no risks this time. The following photographs represents the camera extraction process from ALCATEL tablet which is similar to the extraction process of blackberry smartphone.



Above demonstrates the ALCATEL tablet disassembly process and camera removal step. The camera of the tablet was much smaller compared to the blackberry's camera and the extraction process was more difficult. Eventually the filter was removed, and the parts lens, cover and sensor were ready to assemble back and finally was set to put in the tablet back. The filter removal process and the parts of the camera are shown below in the figure:

Later the near infrared filter was removed from the lens. It was hardly glued with the lens, so we were obliged to break it. After the removal of filter lens and sensor were glued back to form the camera that is able to sense the near infrared spectrum. They were glued together in such a way that no light is allowed to pass from other channel other than the lens. It was left in the sun until the glue was dry and finally put back into the tablet. This time no damage was seen in the wires. Hence this approach proves to be successful in the second attempt.



After the glue was fully set the camera was wired back into the tablet. The tablet was switched on and luckily the camera was working perfectly and was able to sense the near-infrared lights.

3.2.2 CAMERA SYSTEM SETUP WITH THE PLANT

A camera system was setup in the home using DIY concept. The plant was taken from the garden in the house and brought to the experiment with the camera that was built earlier. The main objective the experiment is listed below:

1) Take the image of the plant with the filter less camera.
2) Take the image of the same plant in same position with filter applied.
3) Two images will be taken into consideration for post image processing.
4) The two photos should be taken in a such way that it should exactly overlap with each other. Every pixel should overlap over one another.

The camera system with filter on and off state is shown below:

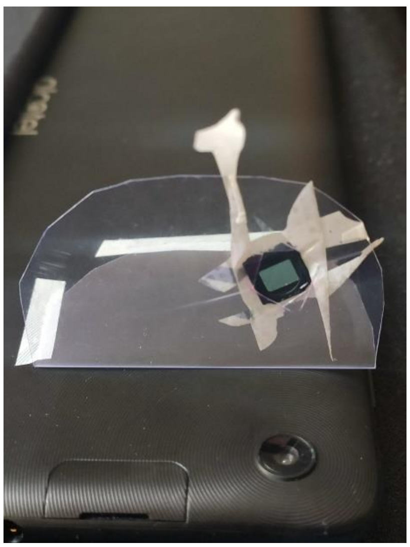


Figure: NIR+RGB Image Setup

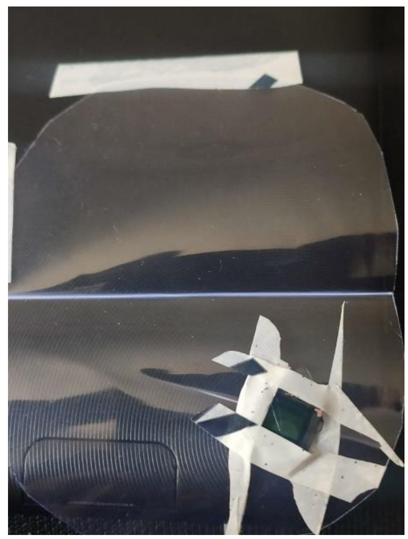
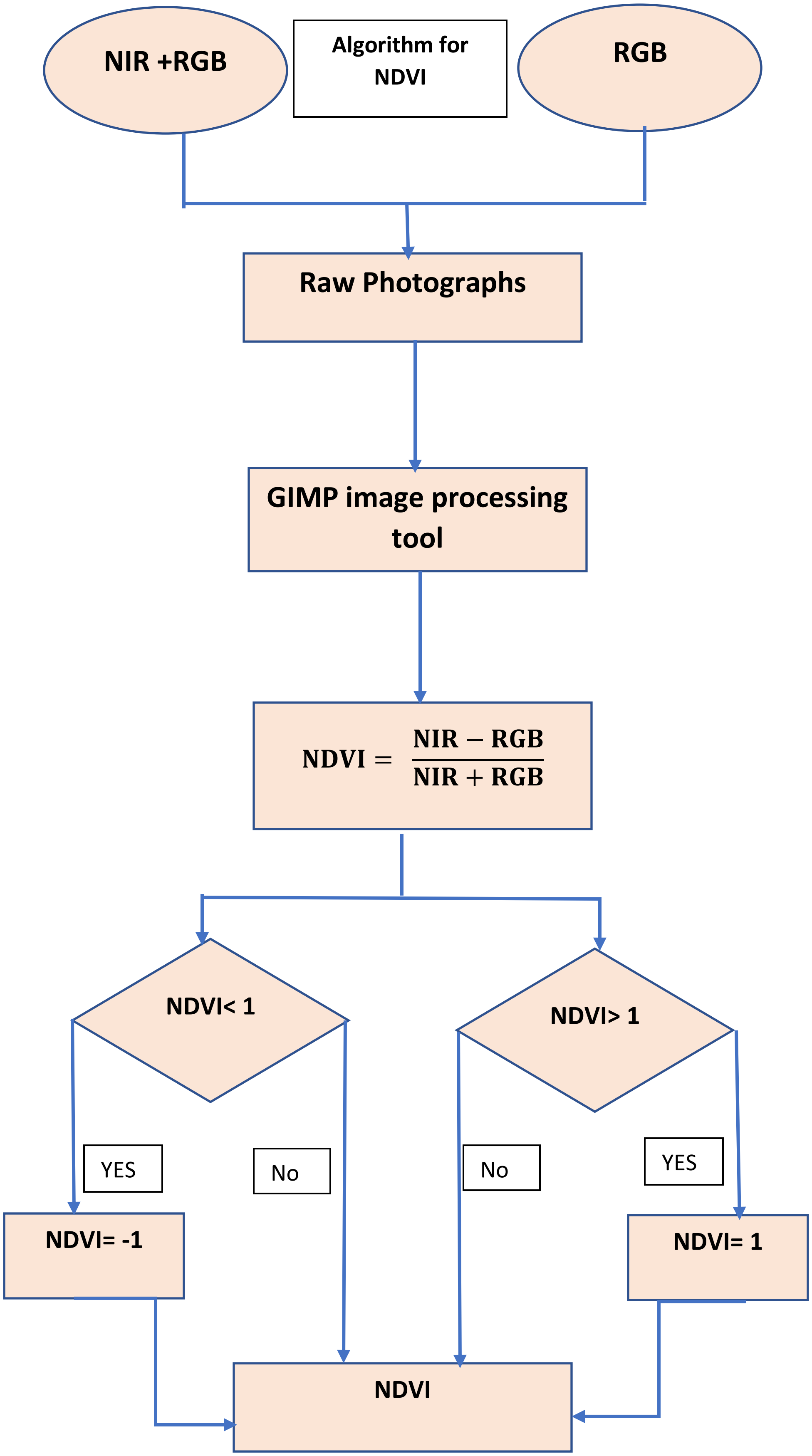


Figure: RGB Image setup with NIR Filter


NIR +RGB
Algorithm for NDVI
RGB
Raw Photographs
GIMP image processing tool
$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RGB}}{\mathrm{NIR} + \mathrm{RGB}}$$
NDVI< 1
NDVI> 1
YES
No
No
YES
NDVI= -1
NDVI= 1
NDVI

4.3 CAMERA SYSTEM

The following camera system is developed to take the picture of the vegetation. The plant is also set along with the camera system in order to take the RGB and Near-infrared images. The modified camera thus obtained is better in taking close objects. This is because during the modification of the camera the focal length of the camera has decreased.

Some of the photographs taken by the system is given below:

4.4 CALULATION OF VEGETATION INDICES

The calculation of the vegetation index NDVI is done by the image processing tool GIMP. This was also explained in the materials and method part. We took the two pictures taken by the RGB and NIR+RGB camera. The two images are taken in same frame so that we get maximum overlapping. Unnecessary noise and distortion are removed using the GIMP tools.

RESULT 1:

Taking the image in the RGB region:

To get the NIR image RGB is subtracted from RGB+NIR to get NIR image.

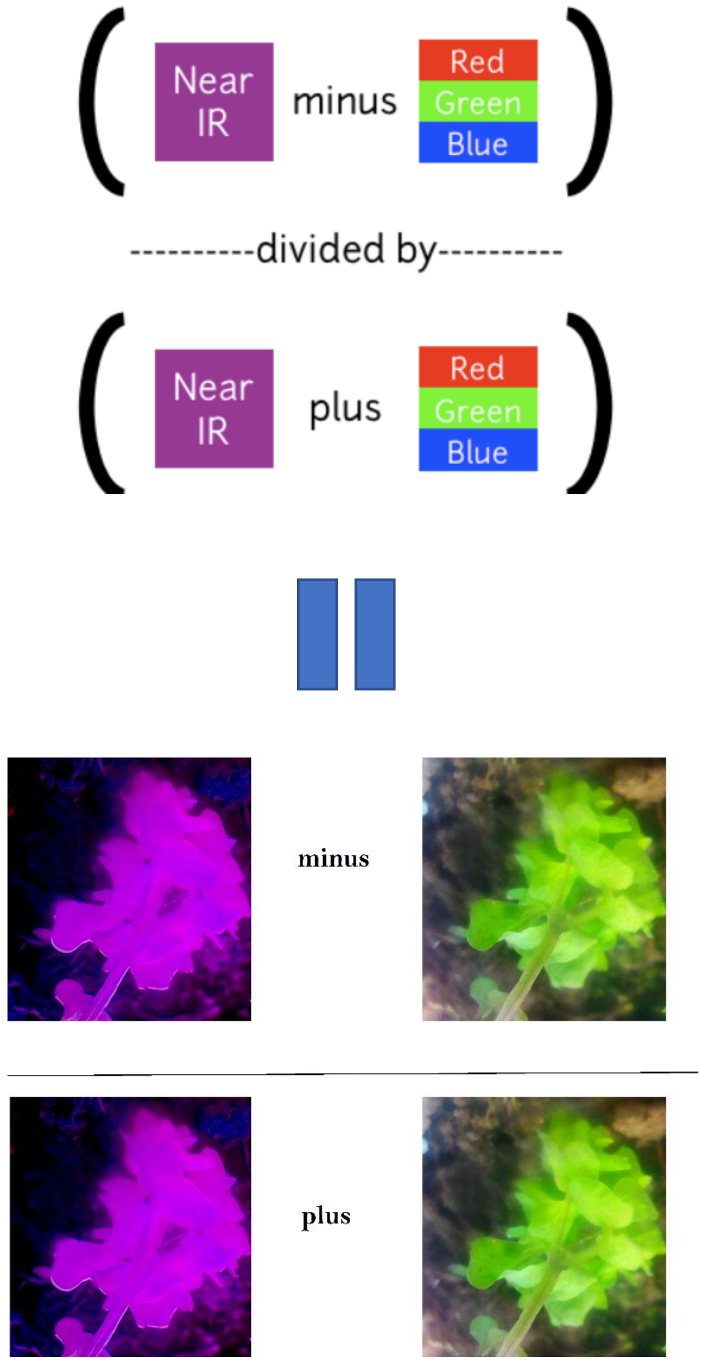
RGB IMAGE

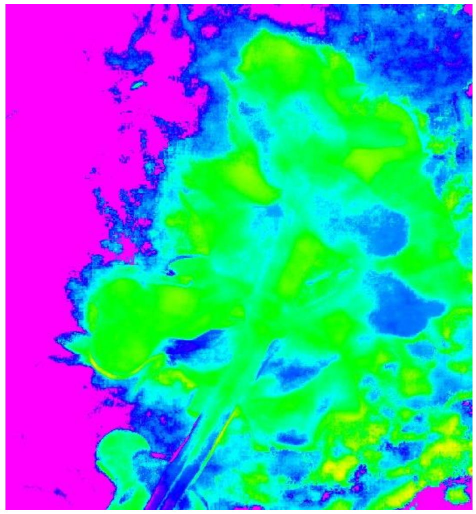
Taking the image without filter:

RGB+NIR IMAGE

NIR IMAGE

Finally, after getting the NIR and RGB images we use the formula to calculate the NDVI as:





NDVI IMAGE

DESATURATED NDVI IMAGE

These two NDVI images are in the false color form and the desaturated form. They both represent the NDVI. The greener part represents healthy region whereas blue areas are soil with low NDVI.

Value of the color ranging from  Magenta to Red. [-1,1].

RESULT 2:

This time Aloe vera plant was taken as the plant object in the experiment. The two photographs in RGB and NIR+RGB spectrum was taken. Later the images were processed to get following results:

RGB IMAGE **(NIR+RGB)IMAGE**

NIR image is taken by subtracting RGB image from RGB+NIR image using the subtract tools in GIMP.

NIR image is hence obtained as shown in the right.

- To calculate NDVI (NIR-RGB) is calculated by subtracting layer RGB from NIR layer in GIMP.
- Then these images are desaturated since we are dealing NDVI here with the brightness of the pixels.
- Later the layer (NIR-RGB) is divided by (NIR+RGB) layer to get NDVI.
- The pictures following demonstrates the results:

NIR IMAGE

(NIR-RGB) IMAGE (NIR-RGB) DESATURATED IMAGE

NDVI in the desaturated form is given below. The brighter image depicts healthy plants and darker areas are soils whose NDVI values are very low.

Figure: NDVI Desaturated

The following NDVI image is plotted as a rainbow color. The color varies from Magenta to Red.

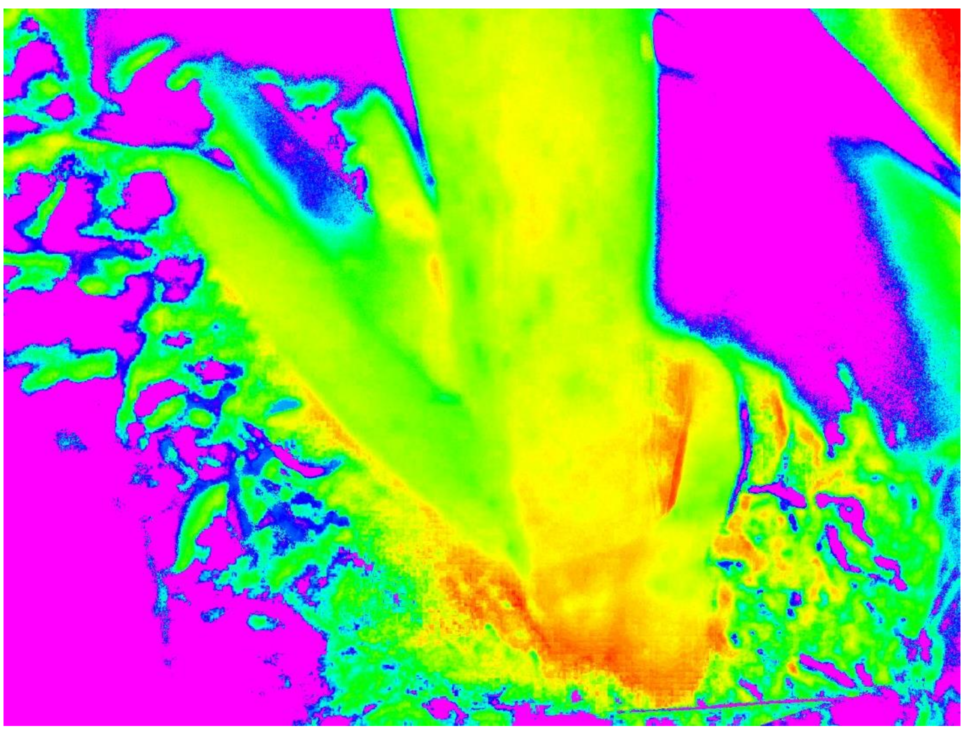


Figure: NDVI false color

5.CONCLUSION AND DISCUSSION:

5.1 Hardware Components of Drone

Selecting the right hardware components without compromising the design requirements is the basis of any design process. In our research we designed the quadcopter and selected the hardware components that best fitted the design requirements. The hardware components chosen for the modeling of the quadcopter are discussed below:

Using the mathematical model presented in [d] we calculated maximum radius of the frame using MATLAB code we prepared. Considering the value of maximum thrust range calculated from 846.15 gram to 1401.47 gram, we predicted the model of motors. Among those models, the best one satisfying the thrust range was found to be Sunnysky X4108S kv690.

Electronic speed controller is another essential hardware part in the design of every multicopter. We should be careful about the fact that the chosen ESC must match with chosen motor. For example, the maximum current the chosen motor can take should not exceed the maximum bearable current capacity of the ESC. According to the motor specification of Sunnysky X4108S kv690, we found that the current capacity of ESC should not be less than 30A.Hence, we gave two options of ESC as shown in the table above.

Propeller is another important part of the propulsion system. Propeller, motor, and ESC should balance each other without any values of voltage or current hampering the system. Thus, Hayoye 12 x 4.5 Propeller was chosen along with 12-inch ATG APC propeller as the alternative.

The heaviest part in the drone design is battery. One should choose the battery capacity according to the design needs, nor less or more, so that the designer can get efficient results. In our quadcopter design we gave the option of two battery capacities 4s 10000mah 25 and 4s 7000mah 40C. The bigger battery(10000mah) is found to offer more hovering time and full throttle time in comparison to smaller battery(7000mah). But if we want to economize our design smaller battery is preferred where we have to decrease the amount of payload as well.

Pixhawk PX4 v2.4.8 32 bit is chosen as the desired flight controller which will be controlling all the propulsion system after the desired coding is uploaded to the controller’s system.

In this category we have GPS, and it is stand, telemetry system, microcomputer, PDB connectors, frame, and anti-vibration damper. The models we chose for the design is specified in the table above.

5.2 Image Acquisition and Image Processing Techniques

Though the drone in this project was virtually designed we experimented some image acquisition methods using the digital camera of smartphone and tablets. This image acquisition method included acquiring of equivalent frame of photograph with and without NIR filter. This was implemented manually with hand so the result might not be ideal. This is due to some overlapping error between two frames. The error was reduced as much as possible using the photo processing tool GIMP. In future we expect to improve this image acquisition by applying an automatic filter using servo motors to minimize overlap error to 0 %. To learn the orthomosaic image processing we took already taken photographs by DJI drone provided by the Drone Camp group from UCANIR. Open source QGIS and ArcGIS trial were used to stich the images together to from orthomosaic. The importance of ground control points, GPS data and metadata in image stitching process were understood and analyzed.

Finally, after the image acquisition NDVI calculation was carried out using the GIMP. We know we were only able to take RGB image and (RGB+NIR) image with our modified camera. Using the subtract function we were able to subtract RGB image from the combination of RGB and NIR image. Later following the NDVI mathematical expression addition, subtraction and division were performed. Note that the brightness data of all the pictures are taken in this kind of calculation. It is recommended to have the image in desaturate mode before starting the calculations. NDVI desaturated image was finally obtained but it could not give us the clear idea regarding the health status of the plant. Because of this reason the desaturated image was converted to false image where color ranged from magenta to red. Magenta represents non-living things such as soils or dead plants whereas red represents healthiest plant.

In future better camera for image acquisition is expected to be used. The drone with camera system is proposed to be low cost so this is also the concern while designing and proposing acquisition techniques for the multispectral image drone for agricultural purposes.

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